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AN EXPERIMENTAL INVESTIGATION INTO THE EFFECTS OF OZONE ON INTELLIGENCE TEST PERFORMANCE

by

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The undersigned hereby certify that they have read and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled, "AN EXPERIMENTAL INVESTIGATION INTO THE EFFECTS OF OZONE ON INTELLIGENCE TEST PERFORMANCE", submitted by Terence Hore in partial fulfillment of the requirements for the degree of Master of Education.

ABSTRACT

The investigation studied the effects of low concentrations (0.2 parts per million) of ozone on the performance of subjects on the Lorge-Thorndike Intelligence Test, Level H, College Edition, Form 1.

The sample was drawn from volunteers from first year Education students from the University of Alberta, Edmonton, Alberta, Canada and divided randomly into treatment, placebo and control groups.

An analysis of covariance design was employed to adjust the measurements on the criterion for possible sources of error which may have been present despite the random assignment of subjects to treatment groups. The covariates were age, sex, anxiety and initial Lorge-Thorndike Intelligence Test score.

The subjects in all three groups took the initial administration of the Lorge-Thorndike, and the IPAT Anxiety Scale Questionnaire in their normal classrooms and the second administration of the same form of the Lorge-Thorndike in the experimental room. Apart from the ozone concentration all other experimental conditions, such as noise, entrances of the technician and position and instructions of the investigator were kept constant, for each group. The exposure time to ozone was approximately sixty-five minutes.

The data indicated that there were no significant differences among the criterion scores for the three groups, on either the verbal or the nonverbal tests, after adjustments had been made for the effects of the covariates.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

In the 'Iliad' and the 'Odyssey' Homer refers to a "freshness in the atmosphere after a thunderbolt or storm". That something new had appeared after lightning was true, but Van Marum in 1785 noticed the same odour in the vicinity of electrical machines. This "something" has a characteristic smell to which it owes its name Ozone, derived from the Greek 'ozein', to smell.

For nearly 200 years the properties of ozone have been investigated by scientists and doctors and have been reported along a continuum from 'stimulating' to 'depressing'. The effects of ozone have been noted, for the most part, in physiological terms, attempting to determine its effects on the respiratory tracts. But Glick (1940) reported a phenomenon which suggested the possibility of ozone affecting mental functioning. He reported that the results of testing freshmen, at Massachusetts State College, Amherst, Massachusetts, U.S.A., during the major part of a hurricane, showed a 20 per cent superiority over the previous ten year average, despite poor illumination, falling trees and the weirdness of both sound and vision which prevailed. Later tests showed this same freshman class to be about average. Glick stated that it appeared plausible that the unusual amount of ozone in the atmosphere served as a mental stimulant. The presence of a large amount of ozone in the air was noted by Peters (1939) and Ritchie (1939) of Massachusetts State College.

The review of the related research shows that ozone is present in industrial smog, and in and around high-flying aircraft. The increasing concentration of industrial smog and the increasing altitude at which passenger aircraft are travelling make it important that the effect of low concentrations of ozone on mental functioning be investigated.

The purpose of this study is to discover if an increase of ozone in the atmosphere has any effect on mental efficiency; specifically it is to test Glick's assumption that an increase in the ozone concentration will lead to an increase in scores on an intelligence test.

CHAPTER II

REVIEW OF THE RELATED LITERATURE ON THE EFFECTS OF OZONE

Huntington (1945), over a period of many years, made a study of the normal ozone concentrations encountered at various locations on the earth. He has statistically analyzed the variation of atmospheric ozone concentrations with respect to various physiological characteristics of mankind. His analysis indicates that both the short and long periods of high mental activity and high reproduction rates occur during the periods of highest ozone concentrations.

An interesting fact brought out by Huntington's studies is that in certain sections of the world the normal ozone concentration frequently exceeds point-one parts per million by volume, which is the Maximum Acceptable Concentration permitted for occupational exposure by the American Conference of Governmental Industrial Hygienists (1960). It is not generally realized that ozone exists in varying amounts over the face of the earth, and even in large cities an appreciable amount of ozone is usually present. Thorp (1950, p.52) says: "Statements in the literature to the effect that ozone is not present in large industrial cities are erroneous".

Renzetti and Romanovsky (1956) stated that the primary component of the oxidant in Los Angeles smog was ozone. It showed a peak at Pasadena, for instance, from eight parts per hundred million at 4.00 a.m. to fifty-five parts per hundred million at noon.

Griswold, Chambers and Motley (1957) confirm Renzetti's findings

and state that in Los Angeles, out of ozone, oxides of nitrogen, carbon monoxide and sulphur monoxide, only ozone has reached the "alert" level; that is, above the threshold level set by industrial hygienists. Feldstein (1963) noted that ozone levels as high as 0.9 p.p.m.[1] have been measured, while ordinary levels during periods of smog may reach as high as 0.2 - 0.3 p.p.m. for extended periods. Jaffe and Estes (1963) state that a combination of meteorological factors, latitude and time of year can affect the position and magnitude of the peak of the distribution of atmospheric ozone.

The use of ozone in air-conditioning has achieved some commercial importance. Ozone concentrations of 0.2 - 0.4 p.p.m. allow substantial reductions in the proportion of outside air necessary in recirculating air-conditioning systems.

The effects of ozone on rubber. Stokinger (1954) reports that ozone is found mainly in the stratosphere where it is formed by the action of ultra-violet light on oxygen, the amount varying with the latitude and time of year. Atmospheric circulation tends to bring some of this ozone down towards the surface of the earth to add to that produced by atmospheric electrical discharges. Ozone concentrations near the earth's surface are normally very small, from zero to a few hundredths parts per million. Even these small amounts cause a relatively rapid cracking of natural rubber. McKee (1961), seeking the cause of the excessive cracking of tires and other rubber goods in

[1]The abbreviation p.p.m. for parts per million is used in the following pages.

storage at an American Army Base in Northern Greenland, found that while the amount of ozone found would be sufficient to cause cracking of tires, the low concentration made it a little difficult to attribute the severe cracking to ozone alone.

The effects of ozone on small animals. The toxic effects of ozone on animals have been described in many papers for well over a century, and recently Thorp (1950) and Stokinger (1954 and 1965) have written comprehensive reviews of this subject.

Stokinger (1957) published the lethal doses for small animals (Table I). LD-50 refers to that amount of ozone which will kill 50 per cent of the animals exposed.

TABLE I

LETHAL DOSES OF OZONE FOR SMALL ANIMALS*

ANIMAL	LD-50 (ppm by volume)
Mouse, Albino, male	3.8
Rat, Albino, male	4.8
Hamster, male	10.5

*Duration of exposure: 4 hours

Stokinger found a marked tolerance to ozone in animals exposed to 1 p.p.m. for one hour, when exposed later to a known lethal dose. Stokinger feels that this may be the reason why no human symptoms

referable to ozone action have been noted in the Los Angeles area despite reports of significant ozone levels. He felt that certain factors modify the toxicity of ozone; four of these, viz, youth, physical exertion, alcohol and respiratory infection, act to the detriment of the host, while others, pre-exposure and intermittent exposure, reduce or eliminate the injurious effects.

The effects of ozone on human beings. Despite the acknowledged presence of ozone few experiments have been done to study the effects of low concentrations of this gas on human beings.

Lagerwerff (1963) stated that it is rather surprising that medical interest in the effects of ozone exposure has been limited almost exclusively to its properties as a pulmonary irritant. In his study eight subjects claimed that the ozone made them feel run down and tired and that they experienced difficulty in concentrating. He states that although similar symptoms have been reported in cases of ozone poisoning it is remarkable that they should become manifest at the relatively low ozone concentrations employed (20, 35 and 50 parts per hundred million by volume). The findings of the study were as follows:-

1) Decrease of visual acuity in the scotopic and mesopic ranges
2) Significant and measurable increase in peripheral vision
3) Individual differences in sensitivity to the effects of ozone exposure.

The symptoms of a volunteer subject exposed to 1.50 - 2.00 p.p.m. for two hours were described by Griswold, Chambers and Motley (1957) as dryness of the mouth and throat, constrictive substernal pains,

decreased ability to concentrate, and a lowering of the vital capacity.[2] The clinical manifestations of the toxicity of ozone in welders using the consumable electrode welding technique have been outlined by Kleinfield and Giel (1956), who agree with Griswold, Chambers and Motley, and by Young, Shaw and Bates (1962) who state that exposures of 0.2 - 0.3 p.p.m. for an eight hour day do not cause impairment of air flow or pulmonary diffusion. Whilst Richards and Taylor (1965) were studying ozone as a major phytotoxicant in crop plants they also noted it as a major source of eye irritation, giving free ozone and ozonides formed from automobile exhausts as the chief offending agents. This would seem to reinforce the statement by McKee (1961) that while some of the unnaturally high ozone concentrations measured in California may be the result of natural causes, there is little doubt that the majority of excess ozone is due to man-made causes related to photochemical smog reactions.

Following Young, Shaw and Bates' (1962) detection of ozone in aircraft flying at 35,000 feet, Bennett (1962) studied this contamination by exposing twelve subjects to concentrations of 0.2 p.p.m. and 0.5 p.p.m. for 3 hours per day, 6 days a week for 12 weeks. The subsequent clinical and radiological examination showed no abnormalities, but in the 0.5 p.p.m. exposure group there was some evidence of slight obstruction in the terminal bronchi and bronchioles, but this returned to normal after six weeks.

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[2]Vital Capacity - The volume of air expired by the most forceful expiration after maximal inspiration (Tuttle & Schottelius, 1965).

The most recent evidence on the effects of ozone (Stokinger, 1965) indicate that ozone, like x-rays, produces chromosomal aberrations and that the combined effects are essentially additive. It causes retardation in the deoxygenation of oxyhemoglobin in the capillaries, and further, the chemical agents which protect against irradiation effect also protect against ozone injury. He indicates that ozone tolerance develops at ozone levels of 0.3 p.p.m., well below the concentration where frank edema occurs. The effects of ozone are not restricted to the respiratory tract.

In summary, the pungent odour of ozone can be detected in very low concentrations, approximately 0.02 - 0.05 p.p.m. by volume. Continued exposure at higher concentrations induces severe coughing, depression and nausea, together with a decrease in visual acuity on the one hand and an increase in peripheral vision and decrease in the basal metabolic rate on the other. Huntington (1945) states that the lungs can apparently absorb oxygen at a higher rate from air containing ozone than from ordinary air; therefore a decrease in the basal metabolic rate[3] will be experienced.

Stokinger's review (1965), which includes evidence for the property of ozone to retard the deoxygenation of oxyhemoglobin in the capillaries, leads one to postulate that if this is true of the capillaries serving the brain, then performance under ozone conditions should be poorer than under normal conditions.

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[3]Basal metabolic rate - The minimum expenditure of energy compatible with life.....The amount of energy expended for the internal needs of the body (Tuttle & Schottelius, 1965).

The exact concentrations needed to produce these effects are the subject of much controversy. This arises partly from experimental difficulties in measuring extremely low ozone concentrations and the complication introduced by Thorp (1950) that the toxicity of "pure" ozone (produced from oxygen) is much less than that of ozone produced from ordinary air which contains oxides of nitrogen. However, the tests cited in the Encyclopedia of Chemical Technology (Vol. 9, 1953) show that even when using a special ozonator designed to produce "pure" ozone the concentration of nitrogen ozides was the same as when using a conventional ozonator under the same conditions.

It is apparent that the opportunities for ozone exposure are increasing, due primarily to the presence of ozone in the following areas:-

1) As the primary component in oxidant smog.
2) In high-flying aircraft.
3) In inert-gas shielded welding.
4) In devices for air purification.
5) Around high voltage electrical machinery.
6) In equipment for water purification.
7) As a chemisterilant for blood, vaccines and sewage.
8) In preserving perishable foods.

With these increased opportunities of exposure to low concentrations of ozone, it is important that some evidence be obtained about the effects of low concentrations on mental functioning. Though the most recent evidence on animals would seem to point out the

improbability of ozone having any effect on mental functioning, the only report we have in this area (Glick, 1940) with humans assumed, without experimentation, that low concentrations were stimulating. It is on the basis of this assumption that the present experiment was designed.

CHAPTER III

DEFINITIONS AND GENERAL HYPOTHESIS

DEFINITIONS

For the purposes of this investigation, the following terms will be employed according to the presented operational definitions.

i) Ozone -- (O_3) an unstable blue gas with a characteristic odour. Produced by the action of ultra-violet light on oxygen, or by an electrical discharge across an air space.

ii) Intelligence -- intellectual ability or mental power, which is the product of genetic endowment and experience. It is not directly measurable; for the purposes of this study it will be thought of as the raw scores obtained on an intelligence test.

iii) Anxiety -- a complex emotional state which will be inferred from the total score the subject obtains on the IPAT[1] Anxiety Scale Questionnaire.

iv) Treatment Group -- subjects who took the second administration of the Lorge-Thorndike Intelligence Test in the ozone-enriched experimental room.

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[1] IPAT - Institute for Personality and Ability Testing, Champaign, Illinois, U.S.A.

v) <u>Placebo Group</u> -- subjects who took the second administration of the Lorge-Thorndike Intelligence Test in the experimental room where ozone was present initially but was allowed to disperse before the testing began.

vi) <u>Control Group</u> -- subjects who took the second administration of the Lorge-Thorndike Intelligence Test in the experimental room, with the complete absence of generated ozone.

GENERAL HYPOTHESIS

The general hypothesis tested in this investigation was:

That people completing intelligence tests, under conditions of increased concentration of ozone, will obtain significantly higher scores than when tested under normal atmospheric conditions.

CHAPTER IV

EXPERIMENTAL DESIGN

THE SAMPLE

In October, 1966 a sample of male and female freshmen in the Faculty of Education at the University of Alberta was selected on the following basis. Four sections of a freshman introductory educational psychology course were randomly selected, and 118 students volunteered from within this group. Out of this total sample, nine subjects were absent when the initial tests were given, and a further ten subjects failed to present themselves at the second testing period, despite reminders in class and follow-up letters. Appendix B shows that the "drop-outs" after the initial testing session, were not significantly different from the final sample, on age, sex, anxiety and initial intelligence test score. The final sample consisted of ninety-nine subjects (65 females and 34 males), drawn from the population of 749 (494 females and 255 males) first year Education students registered as full-time students at the University of Alberta on October 1st, 1966. A Chi Square Test of Goodness of Fit calculated for the final sample (Appendix C) showed the sample to be representative of the population on the sex variable. However, because the subjects were volunteers it was necessary to consider possible sources of bias incurred by the method of selection of subjects. Stokinger (1957) noted that the age factor was important to animals under ozone conditions, and since in this experiment the random assignment to groups may have caused a bias,

it was decided to apply a statistical control for this variable. Controls were employed also for sex and initial intelligence test score. Studies by Mandler and Sarason (1952) and Carrier and Jewell (1966) suggested that anxiety plays a considerable role in test performance. Most studies, notably Sontag et al, (1955), Granick (1955) and Kent and Davis (1957) suggested that anxiety interferes with intelligence test performance. Therefore, statistical control was imposed to control for the differences in anxiety levels between the groups.

THE PSYCHOLOGICAL INSTRUMENTS

The Lorge-Thorndike Intelligence Tests - College Edition.

The College Edition (Level H of the 1964 Multi-Level Edition) of the Lorge-Thorndike Intelligence Tests provides both a Verbal and a Nonverbal Battery in a single booklet. Both batteries are given with definite time limits. Odd-even reliability coefficients are reported in the Manual (Lorge, Thorndike and Hagan, 1964, p.31) as 0.93 for the Verbal Battery and 0.91 for the Nonverbal Battery. Test-retest reliability coefficients, using Form 1 and Form 2 of the test are reported as 0.90 and 0.92 for the Verbal and Nonverbal Batteries respectively. However, the number of cases involved in this calculation was small and the test authors state that these results may be regarded as merely suggestive (Lorge, Thorndike and Hagan, 1964, p.32). As the test was published in 1964 there is as yet little evidence of the equivalence of Form 1 and Form 2. It was decided, therefore, to use only Form 1 in this investigation; in this way, variability resulting

from the use of an alternate form was not introduced.

IPAT Anxiety Scale Questionnaire

Studies by Mandler and Sarason (1952) and Carrier and Jewell (1966) suggest that anxiety plays a considerable role in test performance. The effect of anxiety on the Lorge-Thorndike, Level H, is not known, but since several studies, cited above, suggest that anxiety interferes with intelligence test performance, it was decided that a measure of this variable should be obtained.

The Institute of Personality and Ability Testing published an Anxiety Scale Questionnaire in 1963 which provides an overall anxiety score. The review by Cohen (1965) states:

> "The IPAT Anxiety Scale's impressive systematic research background commends it for use as an overall measure... For a quick measure of anxiety level in literate adolescents and adults, for screening purposes, it has no peer." (p.122)

The reliability coefficients for the total score reported in the Handbook for the Anxiety Scale Questionnaire (Cattell and Scheier, 1963, p.8) are +.93 for a Test-retest coefficient with a one week interval, and +.91 for a Spearman-Brown, Split-half coefficient. The coefficients resulting from studies using the Kuder-Richardson Formula 20 are reported as ranging from +.80 to +.83. (*Ibid*, p.8).

Two types of validity coefficients are reported in the Handbook (*Ibid*, p.7). The Construct validity coefficients range from +.85 to +.90 for the total scale, based upon the demonstrated correlation of the item and anxiety component scores with the second-order general anxiety

factor, (Ibid, p.7), and the External Concurrent validity on a psychiatric criterion, namely, a relatively unreliable clinical consensus is +.30 to +.40.

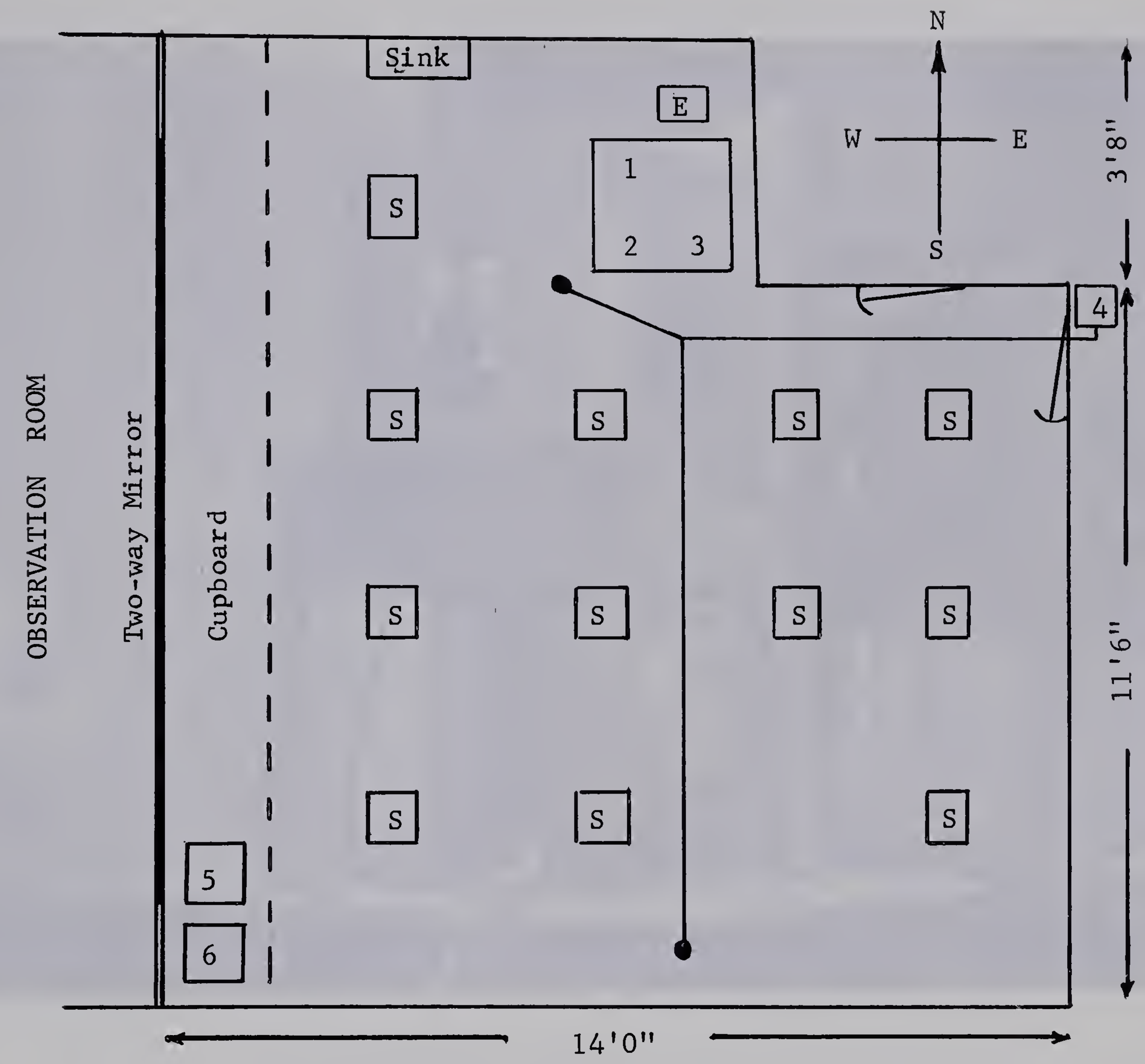
THE EXPERIMENTAL ROOM

The play therapy room of the Education Clinic, in the Education Building, University of Alberta, was used for the second administration of the Lorge-Thorndike Intelligence Test for all the groups. To maintain the ozone equilibrium it was necessary to seal the ventilation grill in the door, and place cardboard strips at the base of the doors. The restricted flow from the air-conditioning unit and an additional fan kept the air circulating. The room has a volume of approximately 1,800 cubic feet (Figure 1).

Figures 2 and 3 show the ozonator, and the ozone meter and recorder respectively.

Floor area approximately 200 sq. ft.

Room volume approximately 1800 cubic ft.



Key

1. Ozone Meter Zero Control
2. Ozone Meter
3. Ozone Meter Recorder
4. German Battery Pump
5. Ozonator
6. Fan

●— Impinger
S Subject
E Experimenter

FIGURE 1

FLOOR PLAN OF THE PLAY-THERAPY ROOM,
EDUCATION BUILDING, UNIVERSITY OF ALBERTA, EDMONTON

FIGURE 2

HOMOZONE OZONATOR AND FAN

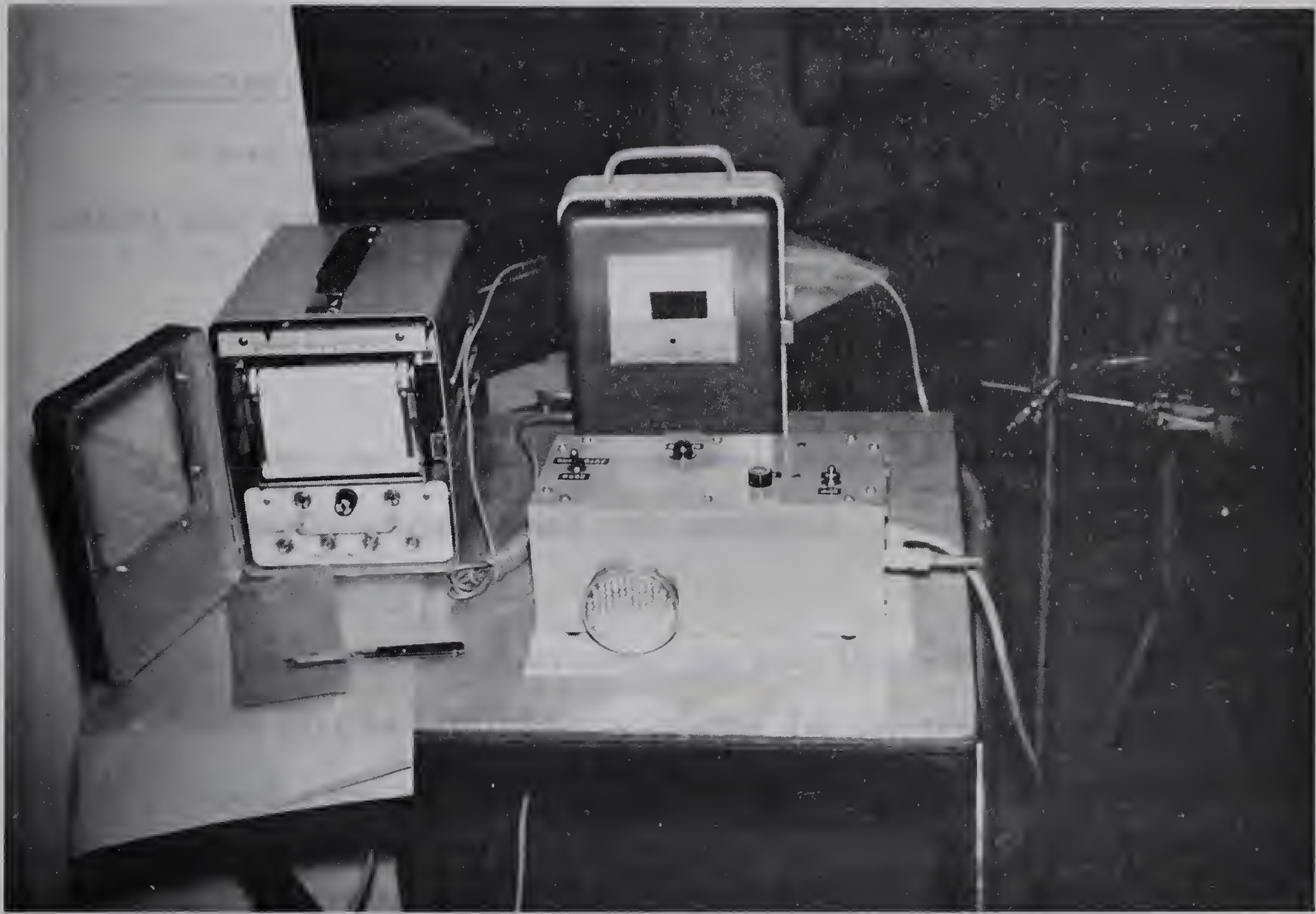


FIGURE 3

OZONE RECORDER, OZONE METER AND OZONE METER ZERO CONTROL

THE TECHNICAL EQUIPMENT

<u>OZONATOR</u> -- Homozone Model SF4, electrical deodorizer.[1]

<u>OZONE METER AND RECORDER</u> -- MAST model 724-C ozone meter

-- MAST model 725-3C Potentrometric Recorder.

<u>SPECTROPHOTOMETER</u> -- Bausch & Lomb Spectronic 20 colorimeter.

A more complete description of the equipment and the analytical methods used can be found in the Appendix A.

OPERATIONAL HYPOTHESES

In order that the general hypothesis could be tested, the following operational hypotheses were generated.

A. <u>Verbal Battery</u>

i) On the second administration, the mean Lorge-Thorndike verbal score will be significantly greater for the treatment group than for the placebo group, after the imposition of covariance control.

ii) On the second administration, the mean Lorge-Thorndike verbal score will be significantly greater for the treatment group than for the control group, after the imposition of covariance control.

iii) There will be no significant difference between the mean verbal scores of the placebo and control groups, on the second

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[1] A.H. Simpson Industries Ltd., 157 Willowdale Avenue, Willowdale, Ontario.

administration of the Lorge-Thorndike, after the imposition of covariance control.

B. Nonverbal Battery

i) On the second administration, the mean Lorge-Thorndike non-verbal score will be significantly greater for the treatment group than for the placebo group, after the imposition of covariance control.

ii) On the second administration, the mean Lorge-Thorndike non-verbal score will be significantly greater for the treatment group than for the control group, after the imposition of covariance control.

iii) There will be no significant difference between the mean non-verbal scores for the placebo and control groups, on the second administration of the Lorge-Thorndike, after the imposition of covariance control.

EXPERIMENTAL PROCEDURE

The project was checked by the Division of Industrial Health Services, Department of Public Health, Government of Alberta, to ensure the safety of the subjects participating in the investigation. The maximum ozone concentration permitted during the investigation was 0.2 - 0.3 p.p.m. by volume. The Division of Industrial Health Services undertook the task of producing the ozone and monitoring the concentration. It was found that an equilibrium could be established in the experimental room by producing ozone continuously to compensate for

that ozone lost through decomposition or escape from the room.

The entire sample was given the IPAT Anxiety Scale and Form 1 of the Lorge-Thorndike Intelligence Test in their normal classrooms on October 14, 17, 18, 20 and 27, 1966. The total sample was randomly divided into three groups; treatment, placebo and control, and then further subdivided into units of twelve subjects, which was the maximum testing capacity of the experimental room.

On November 1, 2, 3, 8 and 9, 1966 the second administration of Form 1 of the Lorge-Thorndike Intelligence Test was carried out for a total of twelve groups, each under one of the three experimental conditions, the maximum exposure time being 70 minutes. The score on the second administration was the criterion measure for this investigation.

No matter which group was being tested the extraneous conditions such as noise of fan or air-sampling pump, the number of times the technician entered, and the position of the experimenter in the room were kept constant. The temperature and relative humidity of the room were measured each day (Table II).

In the trial runs it was found that an equilibrium could be established after running the ozonator for thirty minutes prior to the entry of the subjects, but that the concentration of this equilibrium was lower when people were present in the room due to the absorption of ozone by the subjects' clothing. The average amount of ozone present during the various testing periods is found in Table III, and the concentration present throughout the tests recorded continuously by the ozone analyzer is seen in Figure 4.

The scoring of all the tests was done by hand according to the instructions outlined in the respective manuals. The raw scores were used, in all cases, during the statistical analysis.

TABLE II

THE TEMPERATURE AND RELATIVE HUMIDITY
IN THE EXPERIMENTAL ROOM DURING THE TESTING OF THE THREE GROUPS
(T=TREATMENT, P=PLACEBO, C=CONTROL)

Date	Temperature	Groups	Relative Humidity
Nov. 1, 1966	74.5° F.	T,T,T.	28%
2	75.5° F.	T,P.	33%
3	77.5° F.	C,C,P.	28%
8	74.0° F.	P,P.	32%
9	78.5° F.	C,P.	27%

TABLE III

CONCENTRATIONS OF OZONE PRESENT DURING EACH TESTING PERIOD,
BASED ON A TEN-MINUTE SAMPLING OF THE ATMOSPHERE AND MEASURED
SPECTROPHOTOMETRICALLY (IN P.P.M.)[2]

Date	Treatment	Date	Placebo	Date	Control
Nov. 1	0.22	Nov. 2	0.001	Nov. 3	0.001**
Nov. 1	0.22	Nov. 3	0.001	Nov. 3	0.001**
Nov. 1	0.25	Nov. 8	0.002	Nov. 9	0.000
Nov. 2	0.19	Nov. 8	0.001		
		Nov. 9	0.001		

** See section F of Appendix A

[2]For a more detailed observation of the ozone concentrations see Table XI in Appendix A.

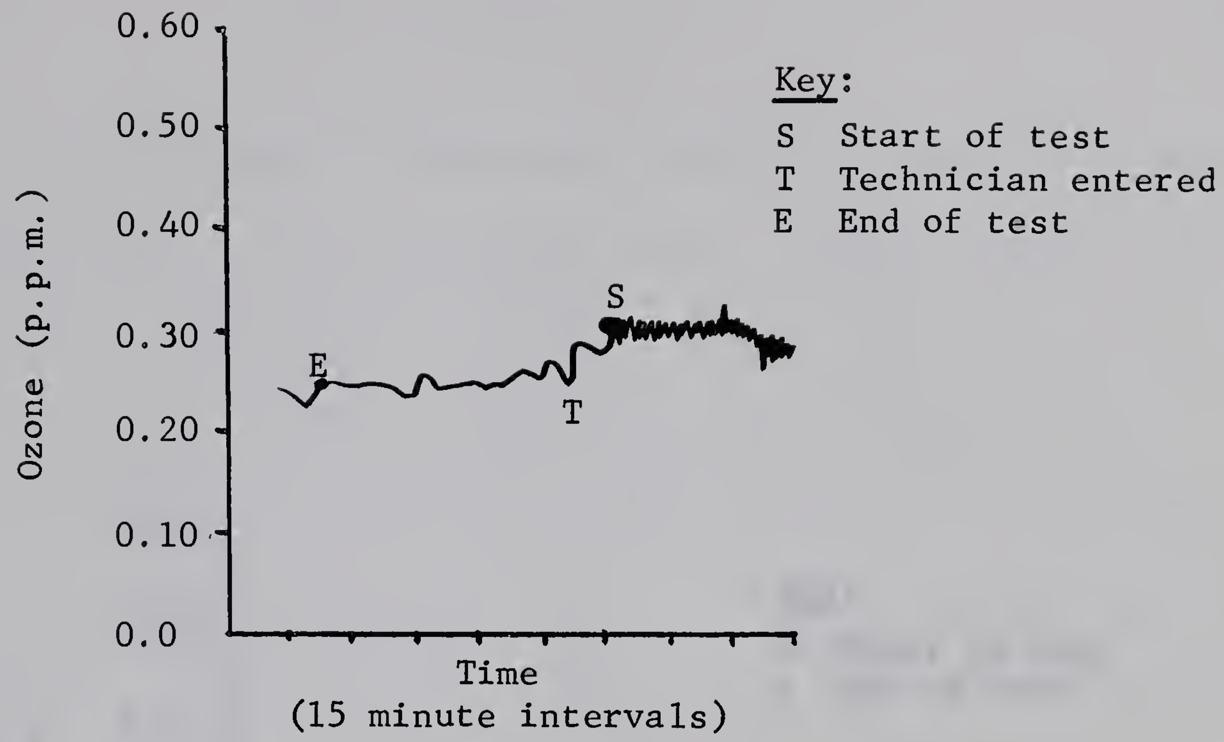

FIGURE 4a

TRACES FROM THE CONTINUOUS RECORD OF THE OZONE MONITOR SHOWING THE OZONE CONCENTRATIONS PRESENT DURING THE TESTING OF THE TREATMENT GROUP

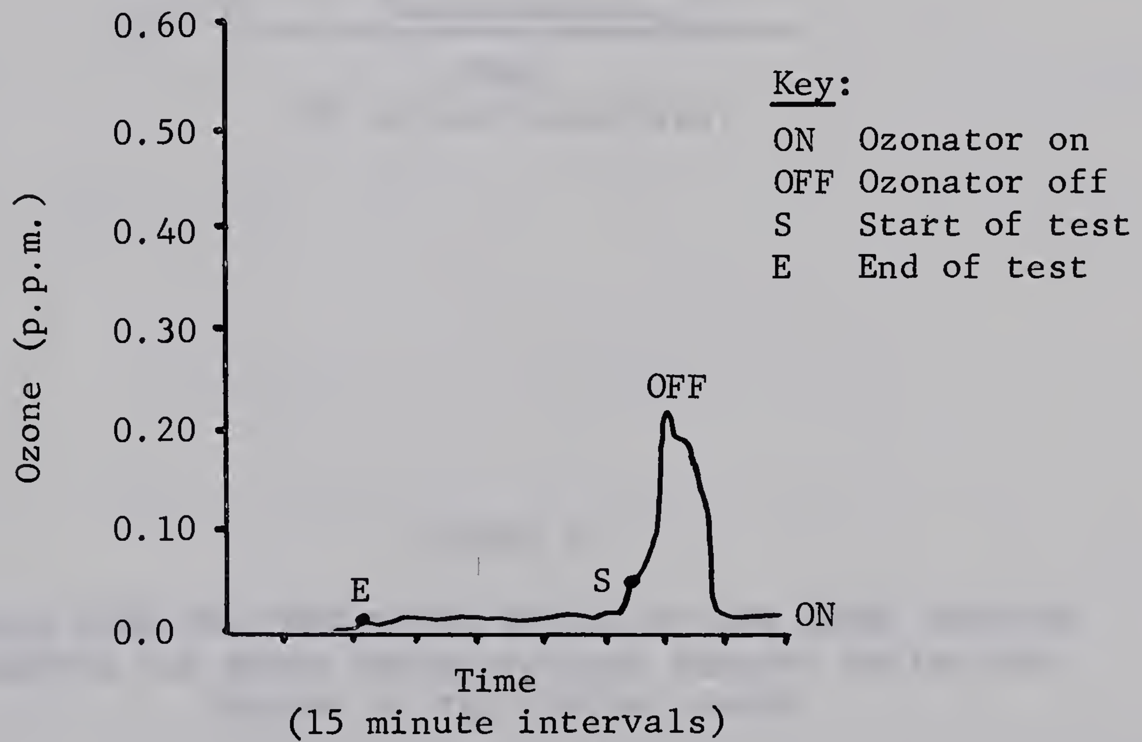

FIGURE 4b

TRACES FROM THE CONTINUOUS RECORD OF THE OZONE MONITOR SHOWING THE OZONE CONCENTRATIONS PRESENT DURING THE TESTING OF THE PLACEBO GROUP

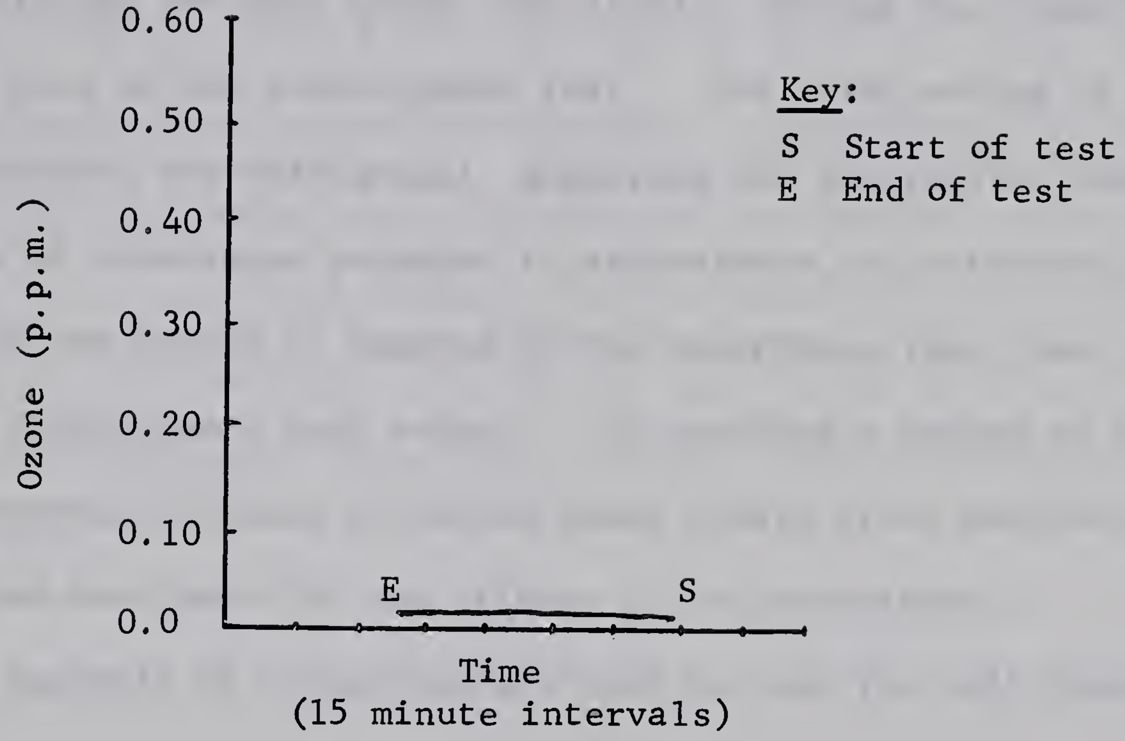

FIGURE 4c

TRACES FROM THE CONTINUOUS RECORD OF THE OZONE MONITOR SHOWING THE OZONE CONCENTRATIONS PRESENT DURING THE TESTING OF THE CONTROL GROUP

STATISTICAL ANALYSIS

There are two general methods for controlling variability due to experimental error - direct and statistical. Direct control consisted of matching the sample to the population on the sex variable, using the raw scores throughout, maintaining the uniformity of the testing conditions for each group, and finally through the repetition of the same form of the intelligence test. The chief method of control in this experiment was statistical, employing the analysis of covariance. The analysis of covariance attempts to approximate the situation in which each of the groups is equated on the covariates (age, sex, anxiety and initial intelligence test score). It provided a method of finding whether differences between criterion means remain after statistical adjustment had been made for the effects of the covariates.

The analysis of covariance was used to test the null hypothesis:

$$H_o: \mu^1_t = \mu^1_p = \mu^1_c$$

where μ^1_t = adjusted mean for the treatment group

μ^1_p = adjusted mean for the placebo group

μ^1_c = adjusted mean for the control group

All the calculations for this analysis were carried out by the IBM 7040 computer at the University of Alberta.

CHAPTER V

RESULTS AND INTERPRETATIONS

Tables IV and V show the result of controlling for the effects of the covariates on the criterion scores of the verbal and nonverbal batteries respectively. Despite the random distribution of subjects into the three groups, some differences were noted in the group means, for the covariates and the criterion scores. The analysis of covariance design attempted to equate these differences and provided an adjusted criterion score. For computational purposes males were represented by the digit 1 and females by 0. In the age calculations the months were represented as decimals of a year, for example, 19 years 3 months was written as 19.25.

TABLE IV

VERBAL BATTERY: THE MEANS OF THE COVARIATES, THE CRITERION AND THE ADJUSTED CRITERION FOR THE THREE GROUPS AND TOTAL GROUP

	GROUP MEANS			
	TREATMENT N=33	PLACEBO N=33	CONTROL N=33	TOTAL N=99
*SEX	0.424	0.303	0.364	0.364
*AGE	21.140	19.162	19.261	19.854
*ANXIETY	28.545	29.364	29.606	29.172
*INITIAL TEST	59.879	61.545	59.667	60.364
**CRITERION	64.212	64.181	62.515	63.636
ADJUSTED CRITERION	64.633	63.174	63.101	63.636

*Covariates
**Second administration of the Lorge-Thorndike Intelligence Test

TABLE V

NONVERBAL BATTERY: THE MEANS OF THE COVARIATES, THE CRITERION AND THE ADJUSTED CRITERION FOR THE THREE GROUPS AND TOTAL GROUP

	GROUP MEANS			
	TREATMENT N=33	PLACEBO N=33	CONTROL N=33	TOTAL N=99
*SEX	0.424	0.303	0.364	0.364
*AGE	21.140	19.162	19.261	19.854
*ANXIETY	28.545	29.364	29.606	29.172
*INITIAL TEST	41.606	42.606	38.697	40.971
**CRITERION	49.576	49.879	47.576	49.010
ADJUSTED CRITERION	49.176	48.512	49.342	49.010

*Covariates
**Second administration of the Lorge-Thorndike Intelligence Test

The analysis of covariance permitted the comparison of the adjusted criterion means for the three groups, and tested the null hypothesis:

$$H_o: \mu_t^1 = \mu_p^1 = \mu_c^1$$

Alpha .05

Decision Rule: Reject H_o if $F_{obs.} > F_{.95}$ (2,92)

Critical Value $F_{.95}$ (2,92) = 3.09 (Ferguson, 1959, 310-313)

TABLE VI

ANALYSIS OF COVARIANCE ON THE ADJUSTED CRITERION MEANS FOR THE THREE GROUPS ON THE VERBAL BATTERY

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES	F	PROBABILITY
TREATMENTS	2	23.010	0.895	0.412
ERROR	92	25.695		

TABLE VII

ANALYSIS OF COVARIANCE ON THE ADJUSTED CRITERION MEANS FOR THE THREE GROUPS ON THE NONVERBAL BATTERY

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARES	F	PROBABILITY
TREATMENTS	2	06.126	0.191	0.827
ERROR	92	32.101		

Decision: Since $F_{obs.}$ = 0.895 (Verbal) and 0.191 (Nonverbal) the null hypothesis cannot be rejected.

The above results indicate that there are no significant differences among the criterion scores for the three groups, on either the verbal or nonverbal tests, after adjustment has been made for the effects of the covariates. The results could have been obtained, four out of ten times for the verbal tests and eight out of ten times for the nonverbal tests, by pure chance alone.

Since the F test did not lead to a rejection of the null hypothesis, no further analysis of the data was required. An examination of the operational hypotheses leads to the following conclusions.

VERBAL BATTERY

Hypothesis A.i) On the second administration, the mean Lorge-Thorndike verbal score will be significantly greater for the treatment group than for the placebo group, after the imposition of covariance control.

This hypothesis was not supported (Table VI).

Hypothesis A.ii) On the second administration, the mean Lorge-Thorndike verbal score will be significantly greater for the treatment group than for the control group, after the imposition of covariance control.

This hypothesis was not supported (Table VI).

Hypothesis A.iii) There will be no significant difference between the mean verbal scores of the placebo and control groups, on the second administration of the Lorge-Thorndike, after the imposition of covariance control.

The finding of no overall difference (Table VI) tends to support this hypothesis.

NONVERBAL BATTERY

Hypothesis B.i) On the second administration, the mean Lorge-Thorndike nonverbal score will be significantly higher for the treatment group than for the placebo group, after the imposition of covariance control.

The data (Table VII) do not support this hypothesis.

Hypothesis B.ii) On the second administration, the mean Lorge-Thorndike nonverbal score will be significantly higher for the treatment group than for the control group, after the imposition of covariance control.

This hypothesis is not supported by the data in Table VII.

Hypothesis B.iii) There will be no significant difference between the mean nonverbal scores for the placebo and control groups, on

the second administration of the Lorge-Thorndike, after the imposition of covariance control.

This hypothesis tends to be supported by the finding of no overall difference (Table VII).

THE VARIABLES

Table VIII reports the correlation coefficients between age, sex and anxiety, and the initial and second administration of the Lorge-Thorndike Intelligence Test.

TABLE VIII

CORRELATION COEFFICIENTS OF AGE, SEX AND ANXIETY WITH INITIAL AND SECOND ADMINISTRATIONS OF THE LORGE-THORNDIKE INTELLIGENCE TEST, LEVEL H, FORM 1, VERBAL AND NONVERBAL BATTERIES, FOR THE TOTAL SAMPLE (N=99)

VARIABLES	LORGE-THORNDIKE INTELLIGENCE TEST			
	VERBAL		NONVERBAL	
	INITIAL ADMINISTRATION	SECOND ADMINISTRATION	INITIAL ADMINISTRATION	SECOND ADMINISTRATION
SEX	.04	.07	.00	.07
AGE	.18*	.17*	-.02	-.07
ANXIETY	-.03	-.03	.02	.03

*Sig. at .10 level, df=97 (Ferguson, 1959, p.315)

The correlation coefficients indicated that knowledge of sex and anxiety added little to the prediction of either the initial or second administration scores. The initial administration scores,

verbal and nonverbal, were also used as a covariate, and these scores alone correlated .90 and .78 with the verbal and nonverbal criterion scores respectively. The multiple correlation coefficients between all the covariates, including the initial intelligence test score, and the criterion or second administration score, were .90 (verbal) and .79 (nonverbal). These results showed that the covariates, sex and anxiety could have been omitted from the statistical design as they added nothing to the predictive power of the initial intelligence test score alone. Knowledge of the age of the subjects appeared to contribute to the prediction of the verbal criterion score, but as this effect operated on the initial test, and as the multiple correlation coefficients did not increase as a result of age being carried as a separate variable, it could also be omitted as a covariate without decreasing the predictive power of the initial intelligence test score.

CHAPTER VI

DISCUSSION AND IMPLICATIONS

On observing the 20 percent superiority of a number of college freshmen's scores on an intelligence test, over the previous ten year average, when these freshmen were tested during a hurricane, Glick (1940) assumed that this superiority was due to the increased concentration of ozone in the atmosphere. The present investigation into the effects of ozone, at concentrations of 0.2 - 0.3 p.p.m. by volume, on intelligence test performance, failed to support Glick's assumption. Table VIII showed that the age, sex and general anxiety level had no effect upon the intelligence test scores. Feldstein (1963) noted ozone concentrations, in California, of 0.9 and it may be that the concentrations used in this investigation were too low. Brown (1950) drew attention to the low barometric pressure at the centre of a hurricane and the work of Frey (1961) indicated that behaviour changes occur as a result of atmospheric ions. He reported that various factors such as heat sources, operating electronic equipment and storms can radically change the ion concentration and the ratio of positive to negative ions. Since ozone and negative ions are produced by similar conditions, it may be that it is not ozone *per se* which produces an effect on mental functioning but the effect of negative atmospheric ions. However, Frey also suggested that stress may be a necessary condition for marked ion effects to appear. Therefore, perhaps the stress and arousal caused by the hurricane, in Glick's students, were not detrimental to intellectual functioning as he suggests, but "optimum", in the Hebbian sense. (Hebb 1955).

SUMMARY

In summary, the present study found the ozone concentrations of 0.2 to 0.3 p.p.m. had no significant effect on intelligence test performance. Future research on this subject should examine the effects of increasing the ozone concentration, increasing the anxiety level of the subjects, varying the barometric pressure and the ratio of negative atmospheric ions. The negative results of this study have some importance, for investigators studying air pollution and for industrial hygienists, as it pointed out that concentrations of 0.2 to 0.3 p.p.m. of ozone have no noticeable effect on mental functioning.

UNHYPOTHESIZED RESULTS

Some interesting facets of the Lorge-Thorndike Intelligence Test-College Level were revealed by the test-retest conditions imposed during this investigation. Table IX reports the means, standard deviations and correlated t-values, all unadjusted, for the three groups, based upon the first and second administration of Form 1 of the Lorge-Thorndike Intelligence Test, Verbal and Nonverbal Batteries. It was expected that the differences within groups would be significant due to the practice effect accruing as a result of taking the same form of the test a second time.

TABLE IX

MEANS AND STANDARD DEVIATIONS OF FIRST AND SECOND ADMINISTRATIONS, FOR THE THREE GROUPS ON THE LORGE-THORNDIKE INTELLIGENCE TESTS AND THE CORRELATED t-VALUES FOR THE SIGNIFICANCE OF THE DIFFERENCE OF MEANS WITHIN EACH GROUP (ALL UNADJUSTED)

LORGE-THORNDIKE INTELLIGENCE TESTS		GROUPS					
		TREATMENT		PLACEBO		CONTROL	
		ADMINISTRATION		ADMINISTRATION		ADMINISTRATION	
		FIRST	SECOND	FIRST	SECOND	FIRST	SECOND
VERBAL BATTERY	MEANS	59.9	64.2	61.5	64.2	59.7	62.5
	STANDARD DEVIATIONS	13.4	12.9*	9.9	9.7*	11.6	11.0
	CORRELATED t-VALUES (df=32)	4.411***		3.321**		3.038**	
		ADMINISTRATION		ADMINISTRATION		ADMINISTRATION	
		FIRST	SECOND	FIRST	SECOND	FIRST	SECOND
NON-VERBAL BATTERY	MEANS	41.6	49.6	42.6	49.9	38.7	47.6
	STANDARD DEVIATIONS	8.0	9.0	8.1	8.6	9.1	8.9
	CORRELATED t-VALUES (df=32)	7.812***		7.384***		8.631***	

*Hartley F-max test (Winer, p.93), carried out on these figures, did not show any significant difference between them. F-max observed = 133. Critical value of F-max$_{.95}$ (df=3,32) 2.40.

**p >.005 (one-tailed)

***p >.0005 (one-tailed)

The differences between the scores on the first and second administrations of the Lorge-Thorndike were highly significant within each group. However, the test-retest reliability coefficients (Table X) indicate that the effect of practice on the verbal battery is a systematic one, with each person achieving an increase, which does not change the rank order established by the first administration to any large extent. On the nonverbal battery the effect of practice is not systematic, and the rank order established on the first administration is not maintained. The reader should bear in mind that these reliability coefficients were affected by the novelty of the testing conditions of the second administration, and as such, cannot be taken as normative data.

TABLE X

TEST-RETEST RELIABILITY COEFFICIENTS FOR THE LORGE-THORNDIKE INTELLIGENCE TESTS, LEVEL H, FORM 1, FOR THE THREE GROUPS (UNADJUSTED)

		GROUPS		
		TREATMENT	PLACEBO	CONTROL
RELIABILITY COEFFICIENTS	VERBAL	0.91	0.90	0.89
	NON-VERBAL	0.78	0.78	0.79

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APPENDIX A

1. Standard Procedure for Colorimetric Determination of Ozone.

A sample of air containing ozone is drawn through an impinger (a bubbling device containing reagents which react with ozone) at a known rate for a known period of time. The ozone in the air sample reacts with the reagents in the impinger causing a colour change which is measured spectrophotometrically and compared to a standard series of known concentrations giving a quantitative determination of the ozone content of the air sample.

A. Reagents.

1. Potassium iodide: 10% $^{w}/v$ aqueous solution using deionized water and stored in a dark bottle.
2. Buffer: Harleco Standard Buffer pH 6.86. Diluted to volume using deionized water (500 ml).
3. Buffered potassium iodide: Combine equal volumes of 10% KI and Harleco buffer solution. (5% KI buffered to pH 6.86.) Stored in a dark bottle, it is stable for 2 weeks.
4. Standard iodine: Prepare a 0.001 N iodine solution from a standard 0.1 N volumetric solution using deionized water. Add 2% $^{w}/v$ KI to this solution as a stabilizer. Stored in a dark bottle it is stable for 2 weeks.

B. Glassware.

All glassware must be washed with dilute nitric acid, then rinsed several times with tap water, followed by rinses with distilled water, and finally with ion-free water. All traces of chlorine or other oxidizing agents must be eliminated. Acetone

must not be used to dry the glassware.

C. Sampling Procedure.

1. Use a standard 30 ml midget impinger containing 10 ml 5% buffered KI solution. Adjust the tip of the impinger dip tube to the indicated correct distance from the bottom of the impinger flash.

2. Sample directly into the impinger as hoses absorb ozone from the air being sampled. The impinger must be mounted vertically.

3. Place a critical orifice of 1.0 litres per minute rating in the sampling line between the impinger and a vacuum pump which is used to draw air through the impinger for a measured period of time.

4. Calculate the volume of air sampled from the duration of sampling and the rated flow of the critical orifice.

D. Standard Series.

1. Add 0.0, 0.1, 0.2, 0.3 and 0.4 ml of standard 0.001 N iodine solution to a series of 10 ml volumetric flasks. Dilute to volume with 5% buffered KI solution.

2. Read the optical density (O.D.) at 390 mμ using a clean, dry, ½ inch matched spectrophotometer tube against a water blank. In this survey, a Bausch and Lomb Spectronic 20 Spectrophotometer was used to determine O.D.

Plot O.D. vs mls of standard 0.001 N I_2 to obtain a calibration curve (See Figure 5).

E. Determination of Ozone Content of Impinger Sample.

1. Read the O.D. of the impinger sample in a clean, dry ½ inch matched spectrophotometer tube at 390 mμ against a water blank.

2. Using the calibration curve (see Figure 5) and the O.D. of the impinger sample, determine the number of ml of 0.001 N iodine corresponding to the O.D. of the impinger sample.

3. Calculate the ozone concentration (ppm) from the formula.

$$O_3 \text{ in ppm} = \frac{11.2\ i}{l}$$

where O_3 ppm = ozone concentration in parts per million of atmosphere

i = ml of 0.001 N iodine liberated in impinger sample

l = litres of air sampled.

F. Interference.

1. Oxidizing agents such as Cl_2 and NO_2 will interfere giving an apparent concentration in excess of the actual ozone concentration. All measurable traces of Cl_2 were eliminated by using deionized water for washing glassware and preparing reagents.

   The NO_2 content of the air did not interfere to a significant degree to be of concern. This evidenced by the extremely low ozone concentrations registered for the control and placebo groups.

2. Reducing agents such as SO_2 and formaldehyde will interfere giving apparent ozone concentrations lower than the actual

concentrations. The relatively high (0.2 ppm) concentrations of ozone determined for the experimental groups indicate that the wet testing method for ozone was not being interfered with by reducing agents.

G. Accuracy.

The critical orifices regulating sampling rate were tested in the Industrial Health Services Laboratory using a Wet Test Meter and were found to allow a sampling rate of 0.95 litres per minute. This correction has been applied to the analytical results. Errors in pipetted volume of reagents and measured time of sampling have been disregarded as insignificant. The factor contributing most significantly to error in the ozone concentration determination is the accuracy with which the spectrophotometer may be read. This was determined to be $\pm$ 0.005 absorbancy units. The limits of the reading error have been indicated on Figure 5 by dotted lines. The maximum absolute error in ozone concentration determination is therefore $\pm$ 0.01 ppm.

The limit of detection by this method is

0.01 ppm with an absolute error of $\pm$ 0.01 ppm.

II. Instrumentation.

A. Hygrometer - Bacharach wet and dry bulb type.

B. Impingers - Standard Midget type, 30 ml capacity.
Safety Supply Co. Ltd. #2000.

C. Critical Orifices - Rated at 1.0 litres per minute. Recalibrated using Precision Scientific Co. Wet Test Meter to 0.95 litres

per minute. Gelman Instrument Co. Limiting orifice set #7012.

D. Pump - Battery Air Sampler, Gelman Instrument Co.

E. Ozone Meter- & Recorder - Mast Model 724-2 Ozone Meter

725-3C Potentrometric Recorder using standard reagent prepared as follows:

10 gm KI

25 gm K Br

1.25 gm Na H_2 PO_3 H_2o

5.0 gm Na_2 HPO_4 12 H_2o

diluted to 500 ml with ion free water, calibrated with a 10 ohm resistor.

F. Ozonator - Homozone Model SF4, electrical deodorizer,

A. H. Simpson Industries Ltd.,
157 Willowdale Avenue,
Willowdale. Ontario.

G. Spectro-photometer Bausch & Lomb

Spectronic 20 Colorimeter - Spectrophotometer

½ inch matched spectrophotometer tubes were used.

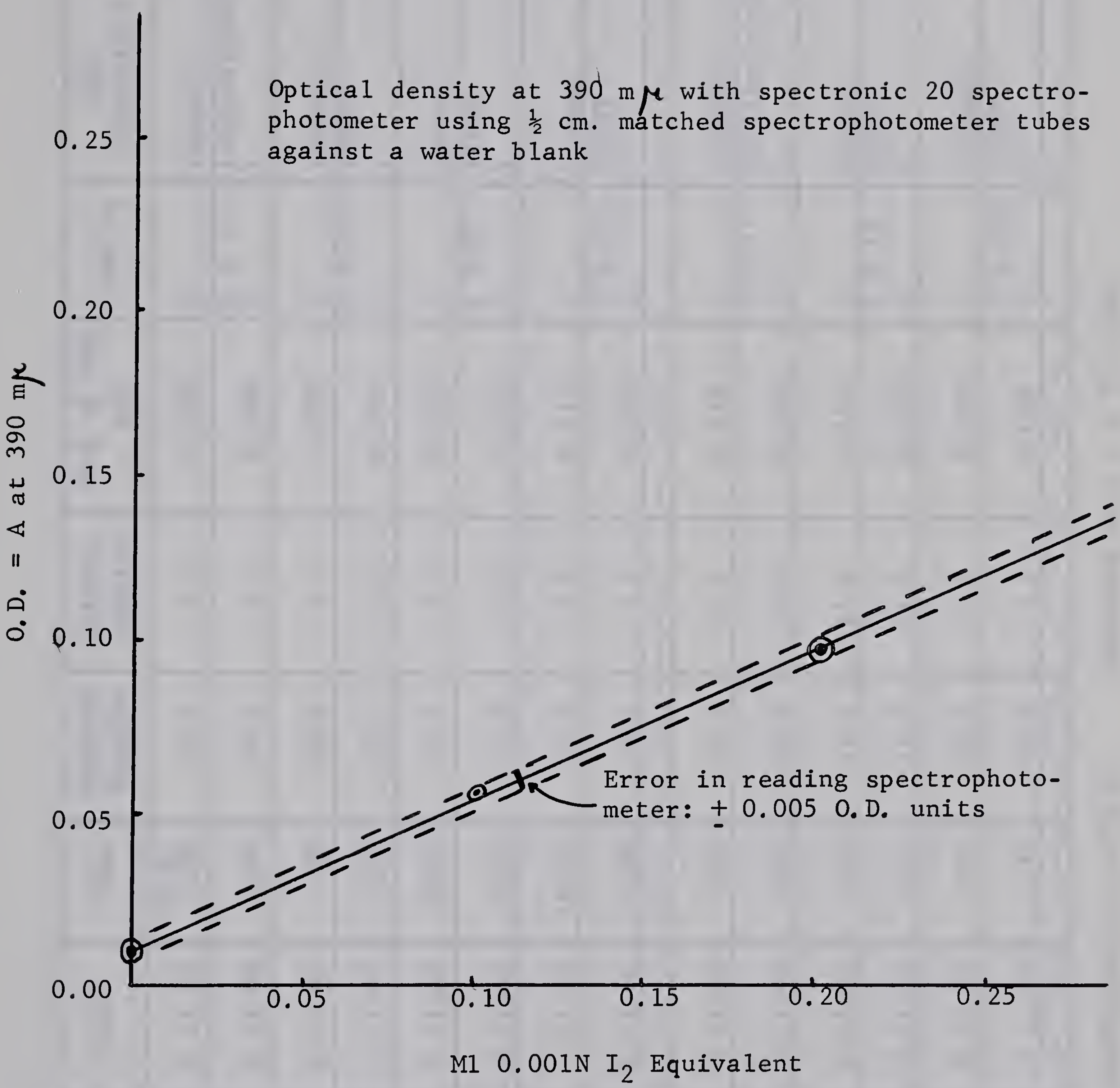

FIGURE 5

OZONE CALIBRATION CURVE

TABLE XI

OZONE CONCENTRATIONS DURING TESTING*

Sample #	Trial	Date	Time	Minutes Sampled	Litres Sampled	O. D. @ 390 mμ	ppm O_3	Test Conditions
661117	1	1.11.66	P.M. 5:00	10.0	9.5	0.110	0.24	ozone
661118	2	1.11.66	5:00	10.0	9.5	0.088		calibration
661119	3	1.11.66	5:30	10.0	9.5	0.103	0.22	ozone
661120	4	1.11.66	5:30	10.0	9.5	0.079		test
661121	5	1.11.66	8:00	10.3	9.8	0.106	0.22	ozone
661122	6	1.11.66	8:00	10.3	9.8	0.082		test
661123	7	1.11.66	10:00	10.3	9.8	0.115	0.25	ozone
661124	8	1.11.66	10:00	10.3	9.8	0.095		test
661125	1	2.11.66	4:45	10.0	9.5	0.119	0.27	ozone
661126	2	2.11.66	4:45	10.0	9.5	0.099		calibration
661127	3	2.11.66	5:45	12.0	11.4	0.103	0.19	ozone
661128	4	2.11.66	5:45	12.0	11.4	0.086		test
661129	5	2.11.66	7:35	10.0	9.5	0.009	0.001	placebo
661130	6	2.11.66	7:35	10.0	9.5	0.008		test

* Method - Spectrophotometric with KI.   Sampling rate - 0.95 1/min.

TABLE XI continued.

Sample #	Trial	Date	Time	Minutes Sampled	Litres Sampled	O. D. @ 390 mμ	ppm O_3	Test Conditions
661131	1	3.11.66	P.M. 5:30	10.0	9.5	0.008	)	)control
661132	2	3.11.66	5:30	10.0	9.5	0.008	) 0.001)	)test)
661133	3	3.11.66	8:00	10.0	9.5	0.005	)	)control
661134	4	3.11.66	8:00	10.0	9.5	0.008	) 0.001)	)test)
661135	5	3.11.66	10:00	10.0	9.5	0.006	)	)placebo
661136	6	3.11.66	10:00	10.0	9.5	0.009	) 0.001)	)test)
661147	1	8.11.66	5:45	10.0	9.5	0.010	)	)placebo
661148	2	8.11.66	5:45	10.0	9.5	0.011	) 0.002)	)test)
661149	3	8.11.66	7:30	11.0	10.5	0.009	)	)placebo
661150	4	8.11.66	7:30	11.0	10.5	0.010	) 0.001)	)test)
661153	1	9.11.66	5:55	11.0	10.5	0.005	)	)control
661154	2	9.11.66	5:55	11.0	10.5	0.005	) 0.000)	)test)
661155	3	9.11.66		10.0	9.5	0.009	)	)placebo
661156	4	9.11.66		10.0	9.5	0.009	) 0.001)	)test)

APPENDIX B

TABLE XII

CHI SQUARE TEST OF GOODNESS OF FIT
OF THE SAMPLE (34 MALES AND 65 FEMALES) TO THE
POPULATION OF FIRST YEAR EDUCATION STUDENTS
(255 MALES AND 494 FEMALES) ON THE SEX VARIABLE

	OBSERVED (O)	EXPECTED (E)	$\frac{(O-E)^2}{E}$
MALES	34	33.6	0.004
FEMALES	65	65.4	0.005
df = 1			$X^2 = 0.009$*

* $p > .95$

In 95 cases out of a hundred a sample drawn at random from the population of first year education students would exhibit the same ratio of males to females as the observed sample.

The actual sample can be considered to be highly representative of the population on the sex variable.

APPENDIX C

A COMPARISON OF THE STUDENTS WHO DROPPED OUT OF THE STUDY AFTER THE FIRST ADMINISTRATION OF THE INTELLIGENCE TEST (N=10) WITH THOSE STUDENTS WHO REMAINED (N=99)

Of the 118 volunteers, 9 were absent during the initial intelligence testing, 22 other students failed to present themselves for the second administration and of these only 10 failed to respond to follow-up letters, and reminders by their classroom instructors.

The following information reports the comparison of these 10 students with the final sample of 99 students, on the variables considered by the investigator to be important; viz. sex, age, anxiety and the verbal and nonverbal scores on the initial administration of the intelligence test.

TABLE XIII

A COMPARISON OF THE STUDENTS WHO DROPPED OUT OF THE STUDY AFTER THE FIRST ADMINISTRATION OF THE INTELLIGENCE TEST (N=10) WITH THOSE STUDENTS WHO REMAINED (N=99)

VARIABLE	MEAN 1*	MEAN 2**	STANDARD DEVIATION 1*	STANDARD DEVIATION 2**	DEGREES OF FREEDOM	t	PROBABILITY (TWO-TAILED)
SEX	0.36	0.30	0.48	0.46	107	0.397	0.69
AGE	19.85	19.85	3.83	1.70	107	0.003	0.99
ANXIETY	29.17	28.40	10.55	12.15	107	0.215	0.83
VERBAL INITIAL TEST	60.36	58.80	11.75	8.33	107	0.407	0.68
NONVERBAL INITIAL TEST	40.97	39.30	8.57	4.90	107	0.600	0.55

* Group 1 (N=99) Final Sample ** Group 2 (N=10) Drop Outs

APPENDIX D

FORMULAE USED IN THE ANALYSES OF COVARIANCE

The adjusted criterion means had the following form, where A, B, C, and D are the four covariates:-

$$\bar{Y}^1_j = \bar{Y}_j - b_a(\bar{A}_j-\bar{A})-b_b(\bar{B}_j-\bar{B})-b_c(\bar{C}_j-\bar{C})-b_d(\bar{D}_j-\bar{D})$$

where $\bar{Y}^1_j$ = the adjusted criterion mean

$\bar{Y}_j$ = the observed criterion mean

b_a = pooled within class regression coefficients for the three groups

$\bar{A}_j$ = mean of group j on covariate A

$\bar{A}$ = total group mean across j groups for covariate A.

The criterion data are adjusted for the linear effects of A, B, C and D through the use of a multiple regression equation which takes the following form:-

$$Y^1_{ij} = b_{y.a_j}(A_{ij}-\bar{A}_j)+b_{yb_j}(B_{ij}-\bar{B}_j)+b_{y.c_j}(C_{ij}-\bar{C}_j)+b_{y.d_j}(D_{ij}-\bar{D}_j)+\bar{Y}_j$$

where Y^1_{ij} = criterion predicted

b_{ya_j} = regression weight based on least squares estimate

$(A_{ij}-\bar{A}_j)$ = deviation score, the distance of an individual's score from the group mean on covariate A

$\bar{Y}_j$ = criterion mean observed.